Preparing for the Press Handstand

E. van de Kerkhof

June 2016

Thesis

Mens en Techniek | Bewegingstechnologie
De Haagse Hogeschool

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2nd supervisor: H. Faber

Preface

This thesis is published to describe a research study conducted from March to June 2016 for the Human Kinetic Technology educational programme of The Hague University located in The Hague, NL.

The cause of choosing this subject to be researched is a result of being active in gymnastics for the last 16 years performing myself as well as coaching children and adolescents. I have noticed the press handstand both being one of the more important basic skills and children being thought the skill quite late in their development as a gymnast. My personal belief is that this is caused by the high requirements of strength, flexibility and motor skills required of a gymnast to be able to perform a press handstand. And my goal that through this study insight can be created of the degree of improvement one has to make to have the bare minimum skills required and a realistic idea of the time it takes to get there.

During this study I have had the pleasure of being guided by many people and would like to thank them for the time they took to help me through the process. First and foremost my two supervisors, Thomas Kolk and Herre Faber, who have checked my progress along the way and guided me writing this thesis. Secondly one of my teachers, Alistair Vardy, who has provided early feedback on the research design and has helped me improve my skills in EMG research. Thirdly, Karen de Vreede, who has annoyed me sometimes by always asking questions why I did things the way I did, but was very valuable in keeping open view to problems and not always resorting to the first solution that came to mind. Finally I would like to thank the board, trainers and gymnasts of D.S.T. Pegasus, who helped me by volunteering to performing their skills at the handstand motion to be used in this study and allowed to convert part of the gym to biomechanical analysis lab.

Personally I have learned a lot about the press handstand motion and I hope the study provides insight for everyone that reads it as well as cause curiosity for the press handstand motion as to provide follow up studies helping more gymnasts and coaches alike.

Delft, June 2016

Erik van de Kerkhof

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Abstract

Being able to perform a press handstand is required to progress to more difficult techniques on almost every apparatus. Therefore it is recommended to learn this skill at an early age. The press handstand requires a combination of high strength, flexibility and motor skills all of which are valued abilities. This study was performed to help gymnasts and coaches alike to provide insight in the press handstand motion, to be able to learn the movement by visualizing which skill, or skills, could be improved to be able to perform a press handstand. Previous research on the subject suggests the required torque decreasing as flexibility increases. Biomechanical equations support these claims. This raises the question "what is the influence of active hip abduction on the anteflexion torque required in the shoulder to perform the press handstand?".

To provide an answer to the question at hand a kinematic model recreating the movement has been constructed based on human static anthropometry retrieved from literature and joint angles obtained from video footage of press handstands. This resulted in an equation to describe the required anteflecting shoulder torque in relation to the hip abduction during the press handstand: $\tau_{anteflection} = -0.11 * \varphi_{hipabd} + 15.52$.

This equation was validated using EMG and video footage from four gymnasts performing five press handstands each. The recorded EMG signal was converted to torques using results from an MVC test to determine the maximal force generated by the shoulder anteflecting musculature measured on the trapezoid muscle and anthropometric properties of each subject. This resulted in establishing that the model in its current form is not valid (r = -0.35, p = 0.12).

Further investigation of the video footage has provided insights as to why this result came about; firstly it became apparent that of the four gymnasts used in the validation, two specific techniques of performing a press handstand have been used, whilst one gymnast was able to switch between techniques at will. During the construction of the model the variance of techniques has not been taken into account. Further research is needed in this field to be able to modify the model accordingly.

The number of gymnasts used in validating the model is a restriction of its own. Only 24.5% of the possible range of hip abduction angles has been used. With this number of people and limited use of the available abduction angles any outliers will have great effect on the validity of the model.

Finally and importantly there is no way to determine whether the torque calculated from the EMG results from the static position of the body segments or the angular acceleration of limbs. Whilst creating the model the angular acceleration has been ignored as in gymnastics it is preferred to perform a press handstand slowly.

The model, invalid in its current stage, suggests a decrease in required anteflecting shoulder torque when the gymnasts' hip abduction increases. Additional research in the field of techniques used during the press handstand is required to provide answer to the question whether and how active hip abduction influences the anteflexion torque required in the shoulder to perform the press handstand.

List of Abbreviations

COM	Centre of Mass
C7	7th cervical vertebra
EMG	Electromyography
Hip joint	Acetabulofemoral Joint
MVC	Momentary voluntary contraction
Shoulder joint	Humeral joint
T8	8th thoracic vertebra
Trapezius	Trapezoid muscle
Wrist joint	Radiocarpal joint
%BW	Percentage of bodyweight
100%MVC	Relationship between maximal torque generated and its' respective voltage
F	Force
g	Gravitational acceleration constant of $9.81ms^{-2}$
I	Moment of inertia
l	Length of the anatomical segment
m	Mass of the anatomical segment
r	Distance from joint to COM
α	Angular acceleration
τ	Torque
φ	Angle

Introduction

The press handstand motion is widely used in gymnastics. It forms the basis for many techniques, such as the Stalder- and Endo-motions on high bar and uneven bars and the Kolyvanov dismount on pommel horse. In this study the motion is performed on the floor from a standing position, in straddled position, the hands are placed in front at shoulder width and after moving the support from legs to hands the legs are raised smoothly to handstand position whilst keeping straight legs and arms (figure 1).

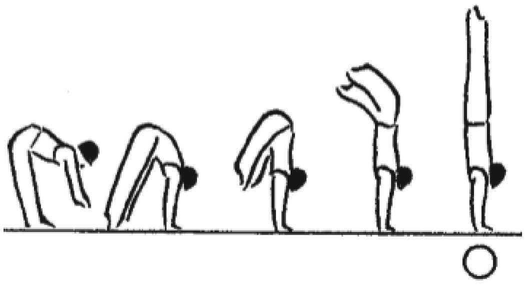

Figure 1: Graphical representation of the press handstand motion[1].

Even though the motion is widely accepted to be very important among coaches, the teaching of this skill isn't a priority to every coach. A possible explanation could be that the obligatory motor skills are high, since this motion requires a combination of great strength, flexibility and balance. Moreover it is necessary to keep the centre of mass close to or above the hands supporting the body. Therefore the shoulders have to move past the hands of the gymnast; to physically be able to do this, one has to achieve large dorsiflexion in the wrist joint. In research about the press handstand motion by Prassas[1] a maximum achieved dorsiflexion of 117 degrees has been found, which is more than the average of 100° pure dorsiflexion available to humans[2]. However, it is possible to achieve this position using either pure abduction[2], a combination of abduction and dorsiflexion, or training the dorsiflexion flexibility of the wrist[3]. The need for balancing the position of the centre of mass also induces a great horizontal distance(r) between the shoulder joint and combined centre of mass of the torso and legs. An extreme case of which is the planche element (Figure 2).

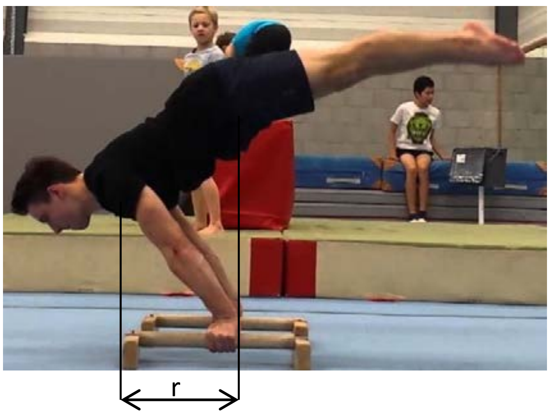

Figure 2: Planche performed on bars where r is the horizontal distance between the shoulder joint and centre of mass, still image from video[1]

The result of which requires large torques in the shoulder joint. Whilst raising the legs there will be a maximum of the torque required to raise the legs further as you pass the planche position. The maximum torque can be reduced by lowering the lever arm between the joint and the centre of mass. Possible ways to reduce these distances is either flexing the knees or abduction in the hip joints. Since in gymnastics the former is prohibited and leads to deductions in the execution score the solution has to be found in increasing the hip abduction.

This raises the question: “what is the influence of active hip abduction on the anteflexion torque required in the shoulder to perform the press handstand?”

The Men’s Artistic Gymnastics Code of Points suggests the press handstand with straddled legs to be a simpler move then the press handstand with pike legs. The former is considered to be a class-A move worth 0.1 points for difficulty, the latter is considered to be a class-B move worth 0.2 points for difficulty in floor exercises. This trend is also visible in the support scale element on rings; the straddled version is a class-B (0.2 points) move where the pike move is values as class-C (0.3 points).

Furthermore research has suggested that hip adductor flexibility is favourable to reduce strength needed to perform a press handstand. Research by Uzunov quotes:
‘Ideal flexibility can off-sets strength requirements, strength gains can make up for lack of flexibility’.[4]

Based on these suggestions in the code of points and previous research it is hypothesized that a greater hip abduction will result in a decreased shoulder torque. However, although it is expected that hip flexibility can reduce the shoulder torque greatly, the motion cannot be performed without some strength. Only the horizontal distance of the legs-COM to the shoulders can be reduced by hip abduction; the COM of the combined torso, neck and head will always keep the same distance to the shoulders.

To provide an answer to the question asked above a kinematic model of the motion will be created where the hip abduction can be varied from 0° (pike) to 90° (maximum straddle) to provide insight in the resulting static torques required. This model will be limited to the sagittal plane, where the abduction will be represented with the legs viewed shorter. The section of the move analysed will be from the point where the toes leave the floor up until the body reaches a 180° angle between torso and legs. As a result the relation between hip abduction and shoulder torque will be expressed in hours of training time to enable coaches and pupils to objectively determine the time it takes to learn the press handstand skill based on the current flexibility and strength capacity of the pupil.

The purpose of this study is to create insight in the relationship between hip abduction and the torques required to perform the press to handstand task by creating a two dimensional model of the motion. The goal of the study is to help coaches with scientific data to be able to determine whether it is more beneficial to train strength or flexibility, with the final objective for the gymnast to learn this skill at an earlier age.

Literature Review

Hip Abduction Effects

Biomechanics supports the hypothesis of reducing required torque if the hip abduction increases. As the press handstand motion is preferably performed at slow speed (in gymnastics this shows the gymnasts' control over their body), it may be considered a semi-static situation. Meaning most of the anteflecting shoulder torque required will be a result of the distance between the joint and the combined COM of the body segments supported by the joint (equation 1). Due to the minimal angular acceleration the moment of inertia will only have minor influence on the torque required as can be seen in equation 2.

$$\tau = r * F \qquad \textbf{(1)}$$

Where:

τ is the generated torque
r is the distance between the centre of rotation perpendicular to the applied force
F is the applied force

$$\tau = I * \alpha \qquad \textbf{(2)}$$

Where:

τ is the generated torque
I is the moment of inertia
α is the angular acceleration

While the mass of the human body is constant, and the angular acceleration is ideally around zero except for initiating and finishing the movement, the amount of torque required can only be reduced by reducing the horizontal distance between the joint and the combined COM of the body segments supported by the joint. This is the primary result of the hip abduction seen in straddled position. A secondary positive result from the straddled position is the combined COM of the torso and legs moving towards the hands supporting the movement. Therefore the shoulders don't have to move forwards as much as with the motion in pike position, resulting in reduced requirements of wrist flexibility.

Strength improvements over time

When gymnasts start to learn to perform a press handstand most gymnasts will not yet have excessive strength and flexibility skills. Therefore for a coach knowing which skill to focus on during the training to progress quickest is desired. Being able to determine the time it takes to improve strength is very important in determining whether it is more beneficial to train strength or flexibility. Research has been done to determine both adults' strength improvement as well as that of children[567]. As this study is most relevant to starting gymnasts as higher level gymnasts are most likely already able to perform a press handstand this study will focus on the improvement that can be expected on children and adolescents.

Three studies[567] were found on strength improvement for children. The general consensus of these studies is that children do benefit from strength training. Two of the studies were provided with statistics of the improvement children made during their respective training duration. In the study by

Sewall[5] 18 children of ages 10 and 11 participated, it has been found that over 9 weeks of training 1.5 hours per week their strength increased by >40% whilst the control group increased their strength by <10%. The study performed by Faigenbaum[6] included 15 children with ages ranging from 7 to 12 years old. Their findings included a significant increase of strength, 41.1% in the training group in comparison to 9.5% in the control group, over the course of 8 weeks of training 2 times a week. The study by Benjamin et al[7] showed an increase of 9-12% in motor unit activation after 10 weeks of training, however no specific strength increase has been provided by this study.

These results show that an improvement in strength of 40% may be expected for a child training 8.5 weeks. It must be noted that the training of strength over time is not linear and earlier progression is much greater then at higher levels of athleticism. Which implies a non-linear relation between the required strength improvements to perform a press handstand and time spent training.

Flexibility improvements over time

As it is with strength the training curve of flexibility isn't linear. The improvements in earlier stages of training are far greater then at an elite level of athletic abilities (Figure 3). Since In gymnastics it may be expected that high- and elite level gymnasts are capable to provide the hip abduction needed, this study focuses on the beginner stages of hip flexibility training.

Improvement of hip flexibility over time is a field that has limited study. Especially in novice level gymnasts. There is one study[8] however performed on 10 physical education students aged 19 to 32 with limited gymnastics experience where the students underwent a 60 day training course with flexibility training 3 times a week. Their hip adductor flexibility was recorded after 14, 30 and 60 days into the course. Results showed that after 14 days the range of hip abduction improved by 6.2° (11.4%), after 30 days improvements were measured at 9.9° (18.2%) and finally at the end of training after 60 days their hip abduction range increased 14.4° (26.4%) (Figure 3).

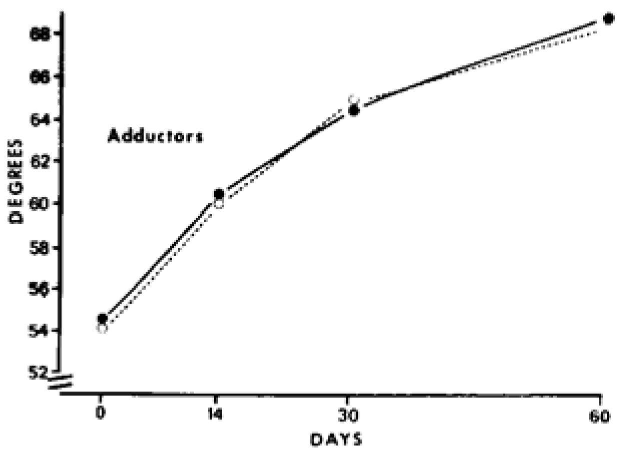

Figure 3: Range of motion improvements of the hip adductors over time[3]

Materials & Methods

Model

The purpose of this model is to recreate the motion of a press handstand in 2D space to determine the maximum torque used in the shoulder joint to lift the body into a handstand position with variable hip abduction.

Constraints

This model will be constructed considering a sagittal view to the motion. To simplify the human body it will be projected as a stick figure with three segments. The upper and lower arms will be combined to an arms segment. The head, neck and torso will be combined to a body segment and finally the upper legs, lower legs and feet will be combined to a legs segment.

Input variables of the model will consist of the following variables:

- The amount of hip abduction
- The hip flexion at the start of the motion
- The relation between hip- and shoulder angles.
- The human anthropometry values, lengths, weights and centres of mass (COM) of each body part, are assumed static and are retrieved from literature by D.A. Winter[9].

The output will be the maximum torque in the shoulder joint for every degree of hip abduction. The torque is normalized to the bodyweight and will be represented as %BW*m.

To determine the required torque in the shoulder joint with different levels of leg abduction, the angle of abduction will be kept constant throughout the motion and only the maximum torque will be recorded. Furthermore, the model will generate output for every full degree of hip rotation from the moment the centre of mass is above the hands until the body and legs are straight with the hip flexion at 180°.

Input variables

Whereas the amount of hip abduction is the intended variable and human anthropometric data can be retrieved from previous research[9], no previous research has been done in the field of techniques used. The technique used by the gymnast includes the angles of the hip and shoulder joints during the press handstand. The hip flexion used by the model at the beginning of the motion as well as the relation between hip- and shoulder angles are retrieved from video footage captured of two individuals performing the press handstand motion (Figure 4). Both gymnasts, one male aged 9 years old at national level and one female aged 14 years old at regional level, were skilled in the press handstand motion; one performed the motion in pike position (no hip abduction) whilst the other performed it from straddled standing position (maximal hip abduction). The hip flexion at the start of the motion was in the case of the motion with pike legs 52 degrees; with straddled legs the hip flexion was found to be 36 degrees both retrieved from video footage analysed with Kinovea v0.8.15.

The relation between hip and shoulder flexion was determined by sampling each video at 0.5Hz and measuring the hip and shoulder angle using Kinovea, the best fitting 2nd degree polynomial was calculated from these data points using the least squares method in Matlab r2014b. For each hip angle used in the model the minimal and maximal shoulder angles used were calculated using these polynomials. For each degree of hip abduction the corresponding starting hip flexion and the relation between hip- and shoulder angles are retrieved by linearly scaling the minimum and maximum values found in relation to the ratio of hip abduction.

Figure 4: Still of videoed press handstand, analysed to retrieve hip and shoulder angles to be used as input for model

Transformations and Calculations

The segment lengths were calculated by the sum of the length of the individual body parts. For the feet the length instead of the height was used to compensate for the stretched toes used to perform the motion in reality.

The segment weights are determined in a way similar to the length; it is a result of the sum of weights of the individual body parts making up the segments.

The combined COM for each segment was calculated by equation 3:

$$r_{segment} = \frac{\sum\left(m_i(l_j + l_i * r_i)\right)}{\sum m \sum l} \quad \textbf{(3)}$$

Where:

$r_{segment}$ is the ratio of length at which the COM is positioned in relation to the joint observed
m_i is the mass of the segment
l_j is the length of the body parts between the segment and the joint observed
l_i is the length of the body part analyzed
r_i is the ratio of length at which the COM is positioned in relation to the adjacent joint

The observed joints are the nearest movable joints, this means that in the case of the arms the observed joint will be the wrists. For the body the observed joints are the shoulders and in the case of the legs the nearest movable joint will be the hip joints.

Using the positioning of the COM and the percentile weight of the body and leg segments the normalized torque is calculated using equation 4.

$$\tau_{anteflection} = m * g * r \quad \textbf{(4)}$$

τ is the normalized generated torque
m is the relative weight of the combined leg and body segments
g is the gravitational acceleration (9.81 ms^{-2})
r is the distance between the centre of rotation perpendicular to the applied force

Output

The results of which are 91 data points of required anteflecting shoulder torque from 0° to 90° hip abduction. A second degree polynomial will be generated through these points to determine the function of required shoulder torque in regards to the hip abduction (equation 5).

$$\tau_{anteflection} = A * \varphi_{hipabd}^2 + B * \varphi_{hipabd} + C \quad \textbf{(5)}$$

In which:

$\tau_{anteflection}$ is the anteflecting torque required in the shoulder joint in %BW*m
ϕ_{hipabd} is the current abduction in the hip joint in °
A,B,C are constants

Validation study

Procedure

Four gymnasts with ages 27.50±3.51 and all of regional level were asked to participate in two tests in succession. The first test consisted of a MVC-measurement to determine the maximum torque of the m. Trapezius pars ascendens and other shoulder anteflecting muscles are able to provide. EMG recordings were made of the m. Trapezius pars ascendens using a TMSI Mobi8 recorder set at 128Hz with electrodes positioned on the m. Trapezius pars ascendens according to Seniam standards[10] 2cm apart on 1/3 of the distance between the 8th thoracic vertebrae and the trigonum spinea (figure 5). The ground electrode was placed on the 7th cervical vertebrae.

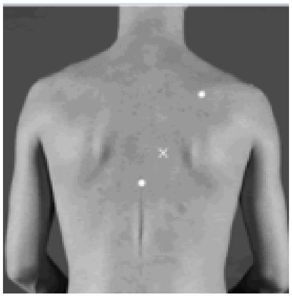

Figure 5: Position of the EMG electrodes for measuring m. Trapezius pars ascendens activity[4]

The produced force at the wrist joint was recorded using a Mecmesin AFG1000N force gauge with a band around the subjects' wrist. To determine the anteflecting torque($\tau_{nteflexion}$) in the art. Humeri, the distance of the tuberculum major humeri to the processus spinosus ulnae was measured(r) and multiplied with the recorded force(F) (equation 6).

$$\tau_{anteflection} = F * r \quad \textbf{(6)}$$

Relating the torque to the EMG signal was done by calculating the envelope of the absolute EMG signal using a 5Hz low-pass Butterworth filter. The maximum EMG value is then determined by averaging the filtered EMG signal over the highest average force generated over a 0.5 second time span (equation 7).

$$100\%MVC = \frac{\int_t^{t+0.5} \overline{EMG}\, dt}{\int_t^{t+0.5} \bar{\tau}\, dt} \quad \textbf{(7)}$$

Where:

100%MVC	is the voltage per Nm of torque at maximal isometric contraction
t	represents the time window in which the average torque was maximal
EMG	is the vector of EMG voltages measured
τ	is the torque vector generated by applying equation 6

During the second test the gymnast performed a maximum of five press handstands. These motions were recorded using the same EMG recorder with the same settings as the previous test. Also a high-speed video recorder, the Casio Exilim EX-FH100, was used to record movement in its sagittal plane 3m left of the subject at 120Hz.

For the purpose of calculating the hip abduction measurements of the length from trochanter major to the lateral malleolus were taken. The degree of hip abduction (ϕ_{hipabd}) was then determined by the goniometric relation between the measured length of the leg (l_{tm-ml}) and the observed leg length (l_{obs}) (equation 8).

$$\varphi_{\text{hipabd}} = \cos\left(\frac{l_{obs}}{l_{tm-ml}}\right) \; (\mathbf{8})$$

Where:

ϕ_{hipabd} is the calculated abduction in the hip joint

l_{obs} is the observed length of the leg retrieved from video in the sagittal plane

l_{tm-ml} is the measured length of the leg in 3D

Statistics

The model will be validated by correlating the predicted torque required to perform a press handstand to the measured maximum torque. Since torque is measured at a ratio scale Pearson's correlation coefficient will be used in this validation study. The coefficient of determination will then be calculated to determine the amount of variability shared by the model and the recorded torques. Both calculations will be performed using SPSS statistics 20.

Results

Model

Based on the general human anthropometric characteristics and assumptions made of the movement the model predicts the required torque gradually decreasing as the hip abduction increases, as can be seen in figure 4. The relation of required shoulder torque and hip abduction this behaviour is represented in equation 9.

$$\tau_{anteflection} = -0.11 * \varphi_{hipabd} + 15.52 \qquad \textbf{(9)}$$

In which:

$\tau_{anteflection}$ is the anteflecting torque required in the shoulder joint in %BW*m

ϕ_{hipabd} is the current abduction in the hip joint in °

Notably the trend is practically linear, even though a second degree polynomial was generated. Furthermore, there is always a minimum of strength required even at maximum abduction. Percentage wise the required torque can be reduced from 100% at pike position (0% abduction) to 15% at straddled position (100% abduction) (figure 6).

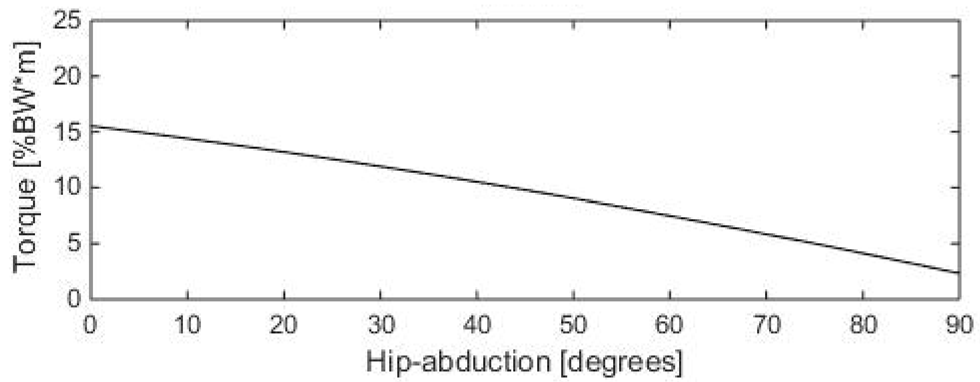

Figure 6: Function representing the relation between shoulder torque and hip abduction in degrees.

Validation study

A combined total of twenty press handstand movements have been analysed. Results of the MVC test show the torques available to the subjects to be 60.76±15.04 Nm. When these values are normalized to bodyweight the results are comparable, namely 0.89±0.22 Nm/kg. Table 1 shows the measured values per subject. Noticeable is the large difference between the minimal and maximal values.

Table 1: Absolute and relative torques available to the subjects during MVC testing.

Subject	τ_{max} [Nm]	$\tau_{max\text{-}normalized}$ [%BW*m]
1	70.58	11.01
2	39.11	5.87
3	71.36	9.58
4	61.99	8.31

Figure 7 shows the results of the recorded press handstands as well as the relationship of the modelled required torque per degree hip abduction. Results from the analysed press handstands have been sorted by the gymnast that performed it to provide insight in the differences between subjects. The correlation between the predicted values and the measured values is determined to be not significant($r = -0.35$, $p = 0.12$). However it is very noticeable every subject has a preferred hip abduction range of around 10° with the exception of subject 3. Also it is clear every subject has a unique combination of torque and hip abduction as can be observed by the distinct grouping of the press handstands performed by each subject.

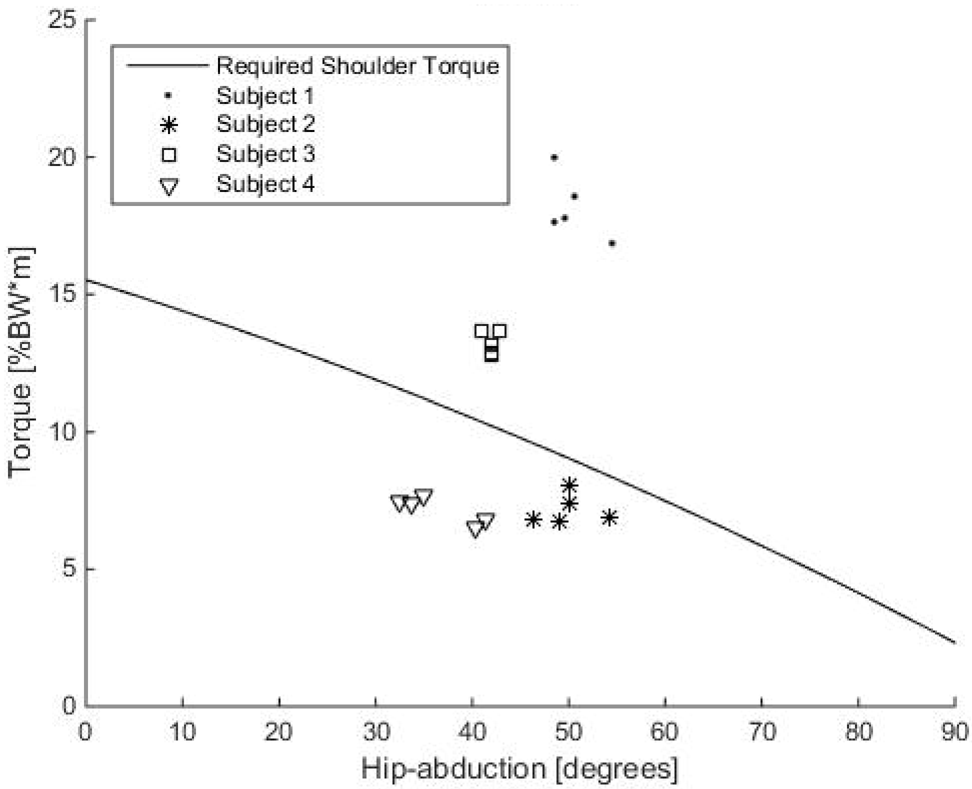

Figure 7: Relative torques measured during press handstands against the maximal hip abduction during the movement.

Discussion

The purpose of this study was to determine the relationship between the level of hip abduction and the required anteflexion torque in the shoulder joint to perform a press handstand and to provide answer to the question: what is the influence of active hip abduction on the anteflexion torque required in the shoulder to perform the press handstand? Literature review, biomechanics and gymnastics coaches suggest that if the hip abduction angle increases the required torque will decrease. This is being confirmed by the static analysis, which was performed by the created model of a press handstand. However, whilst validating this model the results obtained by determining the torques used during the press handstand motion render the model invalid.

This could be explained partially due to the limited number of subjects and therefore range of hip abduction analysed. With a minimal hip abduction angle of 32.4° and a maximal hip abduction angle of 54.5° only 24.5% of the available hip range is utilized by the subjects (Table 2).

Table 2: Hip abduction angles during the recorded press handstand motions per gymnast.

Subject	Hip abduction angle [°]	Minimum angle [°]	Maximum angle [°]
1	50.3±2.5	48.5	54.5
2	49.9±2.9	46.3	54.3
3	49.2±0.7	40.9	42.9
4	36.6±4.1	32.4	41.4

Furthermore, it seems that every subject has a specific technique to perform the motion. Table 3 shows the hip- and shoulder-angles at the start of the motion and at handstand. Whilst each of the gymnasts has consistent hip- and shoulder-angles for each of their press handstands, there is a difference in starting and ending positions. With the exception of subject 1 every gymnast has a consistent sequence of hip- and shoulder-flexion as can be seen in figure 9.

When looking at the averages of the five press handstands a clear difference in technique can be seen, whilst subject 1 and 2 first extends the shoulders and then the hips, both subjects 3 and 4 reverse this order, first extending the hips resulting in nearing a planche position before extending the shoulders (Figure 10). These distinct techniques result in a large difference in lever arms portrayed in figure 8, thus resulting in different torques during the movement.

Table 3: Hip flexion angles at the start of the motion and when achieving handstand per gymnast.

Subject	Starting position		Handstand position	
	Hip angle [°]	**Shoulder angle [°]**	**Hip angle [°]**	**Shoulder angle [°]**
1	55.6±6.2	108.6±4.9	192.8±5.4	150.2±6.0
2	46.4±3.5	130.4±3.6	184.8±11.4	164.0±4.6
3	51.2±1.1	116.2±0.8	198.6±4.7	153.4±1.8
4	59.0±1.6	123.6±1.1	197.6±9.0	149.4±4.8

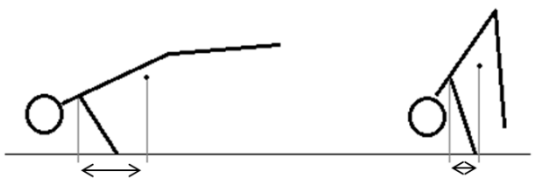

Figure 8: stick figures displaying the variance in lever arm when using different press handstand techniques.

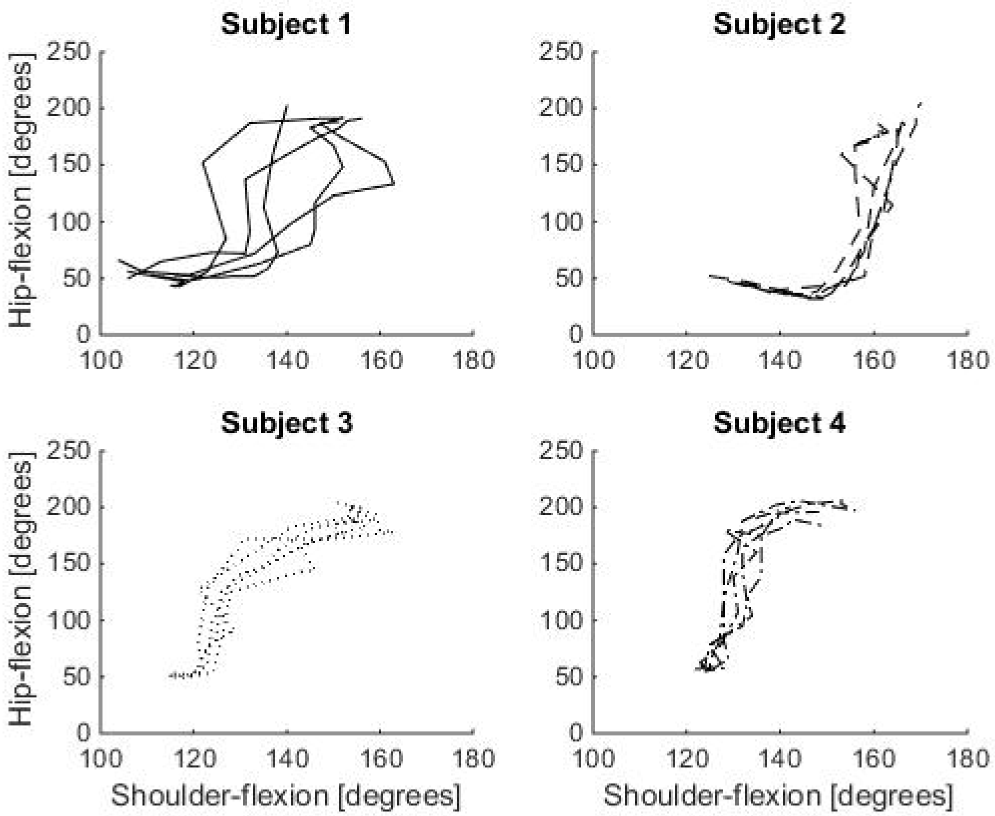

Figure 9: Hip- and shoulder-flexion angles for every press handstand performed by each subject.

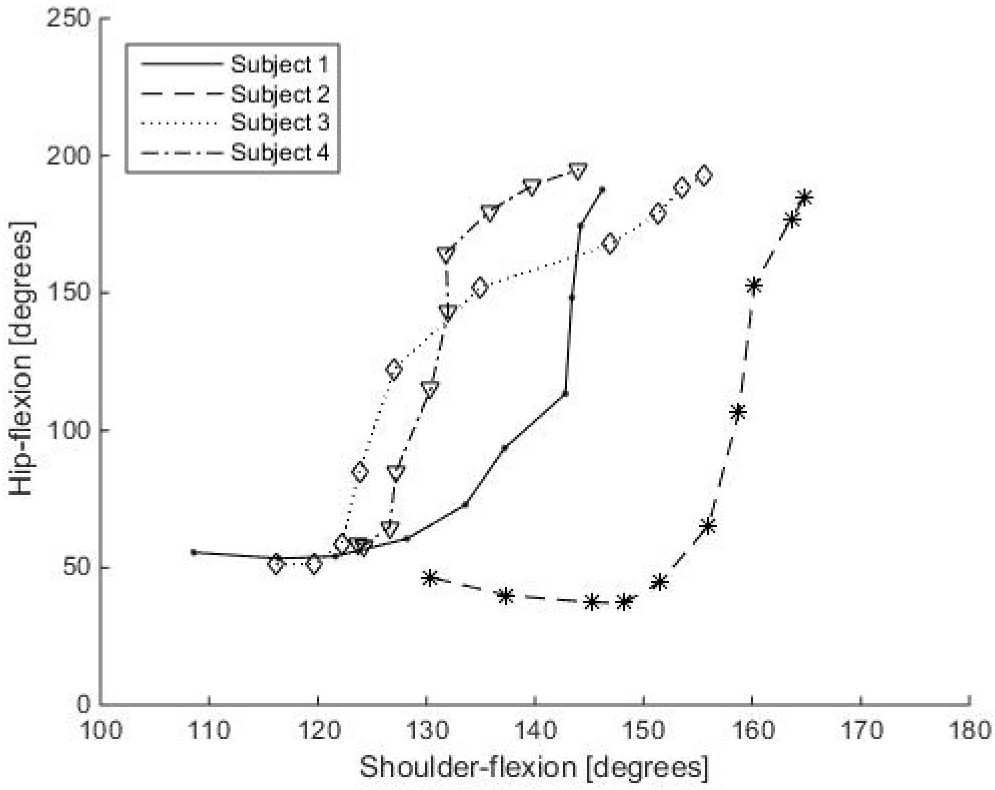

Figure 10: Hip- and shoulder-flexion angle averages for the press handstands performed by each subject.

Fundamentally there is practically always a discrepancy in the measured maximum hip abduction angle and the angle at the time the maximum torque is generated. As the hip abduction during the movement is not constant, and is assumed to be the maximum at the time the torque is highest, it is possible these events occur at different moments in time.

Whilst in the created model it is possible to differentiate between torques generated through static positions and torques generated by angular accelerations, it is not possible to do so by calculating torques through EMG data and the subjects' respective MVC results. Therefore the maximum torques recorded is a combination of both the static situation and dynamic acceleration of the body. This could explain the high torques generated by subject 1 visible in figure 7.

Conversion from required percentile improvements in both strength and flexibility is not possible based on the current level of research in these fields. For strength it would seem possible based on the research; both studies were carried out over a similar timeframe and its results were similar. This, however, is also the limitation. Because there are only two data points linearity can only be assumed. Strength improvements follow a learning curve where improvement becomes harder to accomplish the more you train, therefore the relationship between strength improvement and training cannot be linear. In the flexibility improvement over time study there are multiple data points, so the curve is clearly visible. Unfortunately because the relationship is not linear there is no way of knowing at where the gymnast is regarding its abilities on that curve.

However, clear advantages of the kinetic model approach can be seen. The results of which are normalized and therefore applicable to all gymnasts. Its results are easy to interpret and the graph generated from the equation can be used to visualize the distance between the current abilities of the gymnast and the required abilities. This distance could, with appropriate research, be used to represent the time or effort needed to achieve the goal of being physically able to perform the press handstand motion.

Moreover, even though the method of validating the kinematic model through EMG analysis has its limitations it also has advantages over kinematic analysis. As explained the kinematic model is based on static situations. As it would be impossible, not to mention highly unethical, to accurately determine the exact weights and centres of mass for each body part on a living subject. Using kinematic analysis would use the same assumptions of human static anthropometry as the created model, therefore creating a systematic error. Using EMG measurements to validate does not require any literature based human anthropometry and therefore eliminates the chance of these errors.

Conclusion

This study was performed to help gymnasts and coaches alike to provide insight in the press handstand motion, to be able to learn the movement by visualizing which combination of skills could be improved to be able to perform a press handstand. Which raises the question "what is the influence of active hip abduction on the anteflexion torque required in the shoulder to perform the press handstand?".

A Literature study and biomechanical analysis based on general human anthropometry has found that when the hip abduction angle increases the required shoulder torque decreases. Whist it is possible to greatly reduce the required anteflecting shoulder torque it is not possible to fully eliminate it, even at fully straddled position. However during validation the equation found to describe this behaviour, $\tau_{anteflection} = -0.11 * \varphi_{hipabd} + 15.52$, is not found to be valid ($r = -0.35$, $p = 0.12$). Explanations for this could be the differing techniques used by the gymnasts. With the limited resources available it has not been possible to determine a suitable function describing the relationship between hip- and shoulder-flection angles, also during validation almost every gymnast had a different technique. Furthermore resulting from validating using EMG techniques it is impossible to differentiate between torques resulting from static situations and torques resulting from angular accelerations. Finally the subjects all had a fairly limited preferred range of hip abductions during the motion. Whilst different for each it only covered around 24.5% of possible angles, which is another reason a larger resource pool is preferred.

Due to a combination of the equation generated being invalid it has not been possible to provide baseline requirements of the combination of strength and flexibility. Whilst the research on flexibility improvement over time has been sufficient, there is no way of knowing where on the curve the gymnast currently is and therefore determining the time it takes to improve the percentage needed. On the subject of strength improvement over time the research has been insufficient to recreate the training curve specific to this skill.

Recommendations

Future research is recommended to be done in the subject of techniques used to perform a press handstand. The wrist angle – hip angle – shoulder angle relationship is necessary to be understood before a model describing shoulder torques in relation to hip abduction can be created. This can partially be resolved also by re-validating the model created using more gymnasts and analysing a larger range of used hip abduction angles, preferable with subjects performing press handstands at multiple hip abduction angles spanning the full available range.

Furthermore, it is recommended to do more studies in the fields of strength and flexibility improvements over time, specifically providing results at multiple instances using the same population to determine the training curve.

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Appendices

Appendix 1: Measurement design and protocol (Dutch)

<u>Protocol registratie handstand heffen</u>

Benodigdheden

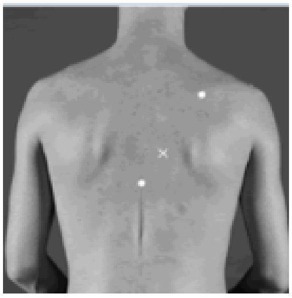
- Mecmesin BFG500N
- TMSI Mobi8
- Casio Exilim EX-FH100
- Laptop
- Meetlint
- Rs232-usb converter
- Weegschaal

Voorbereiding proefpersoon

Kleding: korte turnbroek, strak of zonder shirt, blote voeten

EMG

1. Indien nodig: scheer de huid op de plaatsen waar emg markers komen(stap 4 en 5).
2. Maak de huid schoon met alcohol, laat de alcohol verdampen.
3. Plaats elektroden 1r en 1z op de m.trapezius. Op 1/3 van de lijn tussen Th-8 en trigonum spinae (afbeelding 1) .
4. Plaats de referentie elektrode op de processus spinosus van C-7.
5. Zorg dat de kabels netjes opver de rug lopen, fixeer eventueel met tape.
6. Sluit de kabel vanaf de m.trapezius aan op input a+b



Afbeelding 1: Positie EMG-markers m.trapezius

Video registratie

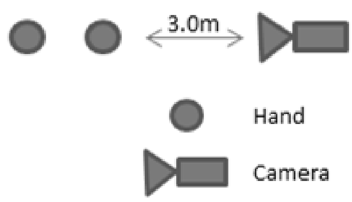
<u>Voorbereiding:</u>

Markers positioneren op de volgende plaatsen op de linkerzijde van het lichaam:

1. Caput ulnae
2. Tuberculum major humeri
3. Trochantor major femoris
4. Malleolus lateralis

Camera instellingen: 120fps, 1080p.

Camera positionering: lens op 0,6m boven de vloer, gepositioneerd op 3,0m links van de proefpersoon in het sagittale vlak (afbeelding 2)



Afbeelding 2: Meetopstelling camera

Metingen

Meting MVC Trapezius:

1. De proefpersoon dient een staande positie met voorwaarts, horizontaal, geheven hand aan te nemen.
2. De band van de krachtopnemer word rond de pols van de proefpersoon geplaatst, let er op dat de krachtopnemer haaks, verticaal, onder de onderarm wordt gehouden.
3. Zet de emg aparatuur en krachtopnemer aan.
4. De proefpersoon neemt 1s rust, maakt een kleine korte hefbeweging en rust 2s.
5. De proefpersoon probeert zo hard mogelijk de arm te heffen, moedig ook aan als onderzoeker. Let er op dat de krachtopnemer en arm op dezelfde plaats blijven(isometrische contractie)
6. Op het moment dat de proefpersoon vermoeid raakt of duidelijk niet een hogere kracht kan leveren is de meting afgelopen.
7. Zet de emg aparatuur en krachtopnemer uit.

Meting Heffen:

1. Meet de lengte van het bovenbeen tussen marker 3 en 4 .
2. De proefpersoon gaat staan op de plek waar later de handen geplaatst worden(afbeelding 3).
3. Zet de camera en emg opname aan.
4. Wacht 5s, de proefpersoon staat hierbij stil.
5. Laat de proefpersoon de arm heffen en dalen.
6. De proefpersoon neemt minimaal 10s rust.
7. De proefpersoon plaatst de handen op gewenste breedte, de voeten in spreidstand
8. De proefpersoon één maal handstand heffen vanuit spreidstand met gestrekte armen en benen.
9. Herhaal stap 6 t/m 8 maximaal 5 maal.
10. Zet de camera en emg opname uit.
11. Verwijder de emg elektroden en daarna het emg apparaat.
12. Verwijder de markers

Appendix 2: Datasheet participating gymnasts

Naam	[redacted]				
Afkorting	Subject 1				
Beenlengte [m]	0.740				
Armlengte [m]	0.543				
Gewicht [kg]	62.9				
MVC [µV/Nm]	10.7747				
Max Koppel [Nm]	70.58				
Beenspreiding	0.43	0.48	0.49	0.49	0.47
	54.5	49.6	48.5	48.5	50.6

Naam	[redacted]				
Afkorting	Subject 2				
Beenlengte [m]	0.840				
Armlengte [m]	0.484				
Gewicht [kg]	65.4				
MVC [µV/Nm]	19.3499 microV/Nm				
Max Koppel [Nm]	39.11 Nm				
Beenspreiding	0.55	0.49	0.54	0.58	0.54
	49.1	54.3	50.0	46.3	50.0

Naam	[redacted]				
Afkorting	Subject 3				
Beenlengte [m]	0.860				
Armlengte [m]	0.560				
Gewicht [kg]	73.1				
MVC [µV/Nm]	11.0885				
Max Koppel [Nm]	71.36				
Beenspreiding	0.64	0.64	0.65	0.63	0.64
	41.9	41.9	40.9	42.9	41.9

Naam	[redacted]				
Afkorting	Subject 4				
Beenlengte [m]	0.853				
Armlengte [m]	0.570				
Gewicht [kg]	73.2				
MVC [µV/Nm]	13.5014				
Max Koppel [Nm]	61.99				
Beenspreiding	0.65	0.70	0.64	0.71	0.72
	40.4	34.9	41.4	33.7	32.4

Appendix 3: Results video analysis of joint angles

subject 1 — Handstand #

	1		2		3		4		5	
Time	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.
0%	111	53	116	53	104	66	106	56	106	50
10%	119	48	123	51	109	56	118	47	113	65
20%	123	51	126	51	119	53	116	43	124	73
30%	134	63	128	52	133	72	115	44	131	72
40%	145	80	133	52	141	99	117	43	132	91
50%	146	93	136	59	150	123	123	56	131	137
60%	146	117	138	73	163	133	127	85	140	159
70%	152	148	135	113	161	153	122	152	147	175
80%	150	167	137	160	151	176	132	187	151	182
90%	145	183	139	188	147	187	147	191	153	189
100%	152	192	140	202	151	188	152	191	156	191

subject 2 — Handstand #

	1		2		3		4		5	
Time	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.
0%	125	52	129	47	133	44	131	46	134	43
10%	133	47	136	40	139	37	140	40	139	36
20%	140	39	146	33	146	36	148	43	146	36
30%	145	36	148	35	148	39	151	43	149	33
40%	146	32	150	41	152	57	156	51	154	44
50%	150	32	158	52	157	93	157	75	158	75
60%	154	53	160	95	156	141	164	115	160	130
70%	162	109	165	154	156	167	153	159	165	173
80%	165	168	169	186	161	173	157	170	166	188
90%	165	181	169	200	161	176	163	179	166	188
100%	161	179	170	204	160	175	161	186	168	180

subject 3 — Handstand #

	1		2		3		4		5	
Time	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.
0%	116	50	115	51	117	51	117	51	116	53
10%	118	49	120	52	120	52	119	52	121	52
20%	124	54	121	63	121	58	123	60	122	58
30%	126	82	125	86	123	78	124	99	121	80
40%	128	125	126	126	129	92	129	139	123	128
50%	143	143	145	170	121	127	135	148	131	172
60%	146	144	163	178	141	183	138	162	147	172
70%	143	165	160	180	157	193	145	181	152	177
80%	151	177	159	194	153	198	155	189	150	185
90%	157	182	155	200	154	201	153	191	159	189
100%	153	192	151	204	156	200	154	196	153	201

subject 4 Handstand #

	1		2		3		4		5	
Time	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.	S.A.	H.A.
0%	125	59	124	58	123	60	124	61	122	57
10%	126	58	123	63	125	57	124	55	123	57
20%	129	66	127	76	125	64	128	58	124	60
30%	128	82	131	107	127	81	125	77	125	79
40%	128	120	130	138	128	119	134	104	132	95
50%	128	158	135	160	131	161	133	121	133	115
60%	131	174	128	180	132	188	136	139	132	142
70%	136	183	136	175	139	202	136	175	132	164
80%	139	187	140	181	144	206	139	193	137	179
90%	140	195	143	189	156	197	146	203	135	191
100%	148	196	150	183	153	203	154	206	142	200

Appendix 4: Abstract (Dutch)

In staat zijn om te handstand heffen, is in het turnen een vereiste om veel, vaak complexe, technieken uit te kunnen voeren. Het is dan ook aan te raden om deze techniek als gymnast vroeg in de ontwikkeling aan te leren. Het heffen naar handstand vereist een combinatie van veel kracht, lenigheid en een goede motoriek. Deze vaardigheden zijn tevens afzonderlijk van elkaar belangrijk binnen de gymnastiek. Dit onderzoek is uitgevoerd om gymnasten en coaches inzicht te geven in de beweging, met als doelstelling een objectieve blik te werpen op welke vaardigheden een turn(st)er moet verbeteren om het handstand heffen sneller te beheersen. Eerder onderzoek en waardering door de FIG suggereert dat het benodigde moment afneemt als de beenspreiding toeneemt, biomechanische wetten bevestigen dit. Hieruit vloeit dan ook de vraag voort: “welke invloed heeft de mate van actieve beenspreiding op het benodigde anteflectie moment in het schoudergewricht tijdens het heffen naar handstand?”

Om antwoord te geven op deze vraag is een kinematisch model geconstrueerd dat de beweging simuleert op basis van menselijke statische antropometrie en gewrichtshoeken uit videoregistraties van hefbewegingen. Hieruit volgde een vergelijking die het benodigde maximale schouder anteflexie moment uitdrukt tegen de uitgevoerde heup abductie: $\tau_{anteflectie} = -0.11 * \varphi_{heupabd} + 15.52$.

De validatie van deze vergelijking is vastgesteld middels een onderzoek waarbij EMG en videodata is verzameld van 20 handstanden. Hierbij is door middel van een MVC test de EMG vector omgezet naar momenten en hieruit is het maximaal uitgevoerde moment gecorreleerd met het voorspelde benodigde moment. Echter bleek hieruit dat het huidige model niet valide is ($r = -0.35$, $p = 0.12$).

Na grondige analyse van de videobeelden zijn er een aantal aanwijsbare redenen die dit resultaat kunnen verklaren. Ten eerste bleek dat door de proefpersonen twee verschillende technieken gebruikt werden, waarbij de verschillende technieken een verschillende volgorde van het strekken van schouders en heupen hebben. Eén van de proefpersonen was zelfs in staat beide technieken toe te passen. Het model is echter gebaseerd op de aanname dat eerst de schouders en daarna de heupen gestrekt worden. Er zal onderzoek uitgevoerd moeten worden om de effecten van de volgorde waarin gewrichten gestrekt worden te kwantificeren en het model hierop aan te passen.

Een verdere restrictieve van het model is het beperkte aantal proefpersonen dat geanalyseerd is. De proefpersonen hadden allen een voorkeursbeenspreiding. Door het aantal proefpersonen is maar mogelijk geweest 24,5% van het totale bereik van heup abductie te analyseren. Het beperkte aantal proefpersonen heeft ook tot gevolg dat elke uitschieter grote effecten heeft op de validiteit van het model.

Ten slotte is het niet mogelijk om binnen het EMG signaal te differentiëren tussen momenten ten gevolge van de hoekversnelling of de statische positie van het lichaam. Binnen het model is de hoekversnelling verwaarloosd met de reden dat vloeiende rustige bewegingen binnen turnen gewenst zijn, daar deze beheersing van het lichaam laten zien.

Het huidige model suggereert, hoewel niet valide, wel een daling in het benodigde anteflecterende schoudermoment bij een grotere beenspreiding. Er is meer onderzoek nodig naar de effecten die verschillende technieken hebben op de hefbeweging om antwoord te kunnen geven op de vraag welk effect een grotere actieve beenspreiding heeft op het benodigde maximale moment binnen het heffen naar handstand.

Appendix 5: Personal goals (Dutch)

Persoonlijke Leerdoelen

Beroepsspecifieke Competenties
Competentie: Bewegingsanalyse (B1)
Leerdoelen: Het toepassen en verbeteren van mijn vaardigheden met de aparatuur, kennis van de theorie en helder verklaren van de resultaten.
Acties: Veel onderzoek doen naar hoe ik van het ontderzoeksidee kom tot de gewenste uitkomstmaten.

Algemene Beroepsgerichte Competenties
Competentie: Communicatie (A6)
Leerdoelen: Het opstellen van een goedlopend helder wetenschappelijk artikel. In overleg mogelijk in het engels.
Acties: De rapportage die ik doe regelmatig na laten lezen door meerdere personen. Ik heb de neiging van de hak op de tak te springen en ik kan deze tips goed gebruiken om het verhaal helderder te maken.

Persoonsgebonden Competenties
Competentie: initiatief & aanpassingsvermogen (P10)
Leerdoelen: Ik vind het lastig om initiatief te tonen naar mensen die mij niet bekend zijn, dit wil ik makkelijker maken.
Acties: Het verzamelen van proefpersonen in een specifieke doelgroep verplicht mij om contact te zoeken met verschillende turnverenigingen.

Evaluatie

Tijdens deze afstudeerperiode heb ik getracht mijzelf te verbeteren in de bovenstaande punten, in grote delen is dit ook zeer geslaagd. Hieronder staat een korte evaluatie per competentie uitgewerkt:

<u>Bewegingsanalyse</u>

Het verbeteren van mijn kennis en vaardigheden met betrekking tot meetapparatuur is zeker geslaagd, ik heb geleerd om EMG onderzoeken volgens europese richtlijnen uit te voeren en heb zeer veel kennis opgedaan wat betreft de krachtopnemer. Zelf heb ik ook nog een aantal dagen gewerkt aan een manier om deze real time uit te lezen. Het helder verklaren van de resultaten is iets minder duidelijk naar voren gekomen, daar dat de resultaten niet altijd overeen kwamen met de verwachtingen.

<u>Communicatie</u>

Uiteindelijk is het een verslagvorm geworden in plaats van een artikelvorm, naar mijn mening is het qua leesbaarheid voldoende duidelijk, maar dit oordeel laat ik aan de lezer. Het schrijven van het verslag in de engelse taal was een uitdaging en een kans om deze kwaliteiten ook te tonen. Het proeflezen is nuttig geweest voor de manier waarop ik het verslag gestructureerd en geformuleerd heb, hoewel dit niet op gezette tijden gebeurde.

<u>Initiatief & Aanpassingsvermogen</u>

De grootste uitdaging van dit project lag voor mij in het zoeken van proefpersonen. Ik blijf dit nogsteeds lastig vinden maar ik heb hier wel stappen in gezet. Ik heb contact gezocht met vier turnverenigingen waar ik contacten had, uiteindelijk heb ik hierdoor ook een aantal proefpersonen gevonden die wilden helpen. Ook werd er vanuit verenigingen positief gereageerd op het onderzoek, meerderen hebben aangegeven de resulaten graag te willen horen na afloop van het onderzoek.

<u>Conclusie</u>

De afgelopen weken heb ik veel compententies laten zien die ik geleerd heb tijdens de opleiding Bewegingstechnologie. Ook heb ik mij nog kunnen ontwikkelen in mijn mindere kwaliteiten en meen te hebben getoond hier voorgang in geboekt te hebben. Soms was dit leuk en soms was dit lastig, maar achteraf kijk ik hier positief op terug.

Appendix 6: Project design (Dutch)

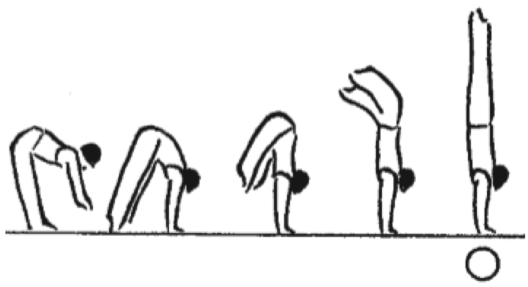
De relatie tussen heup lenigheid en benodigde moment om te kunnen heffen naar handstand

Informatie

Persoonlijk		**Project**	
Naam:	Erik van de Kerkhof	Werkveld:	Onderzoek
Studentnummer:	11096926	Beroepsrol:	Onderzoeker, analist
E-mail:	e.vandekerkhof@student.hhs.nl	Intern/extern:	Intern
Studiepunten			
Mod 9 t/m 12:	36		
Vrije studiepunten:	31		
Minor: schakeltraject	verwacht 12 februari 2016		
Stage 2:	verwacht 4 maart 2016		

Inleiding

Het heffen naar handstand is een element dat bij vrijwel elk toestel, sprong daargelaten, geturnt kan worden. Voorbeelden hiervan zijn de Tippelt-techniek op de brug met gelijke leggers, het Endo- en Stalder-spreiden op het rek en de brug met ongelijke leggers en de Kolyvanov afsprong op voltige. Het betreft een beweging, in dit geval uitgevoerd op vloer, waarbij vanuit een spreidstand in een langzame vloeiende beweging de handen geplaatst worden en de benen gestrekt geheven worden naar handstand (figuur 1).



Figuur 2: Grafische weergave van het handstand heffen.

Hoewel het belang hiervan algemeen erkend wordt, heeft het aanleren van deze beweging niet bij alle coaches prioriteit. Mogelijke reden hiervan is dat het een zeer technisch element betreft dat daarbij zeer veel kracht vereist. Vereist in de beweging is dat het lichaamszwaartepunt (LZP) boven het steunvlak tussen de handen geprojecteerd blijft zodat het lichaam in balans is. Om dit mogelijk te maken is het noodzakelijk de schouders voorbij de handen te bewegen. Dit vereist een lenigheid van ongeveer 30° radiaalabductie. Waarbij een heupflexie gevraagd wordt van 130°. Over het algemeen zal dit niet voor problemen zorgen, gezien deze waarden binnen de mogelijke bewegingsuitslagen in het pols- en heupgewicht van de gemiddeld lenige mens liggen[1]. Dit zorgt echter wel voor een groot anteflexie moment dat geleverd zal worden in het schoudergewricht. Verder zullen de benen geheven moeten worden door een horizontale positie heen, wat resulteert in grote retroflexie momenten binnen het heupgewricht. Beide momenten en gevraagde gewrichtshoeken kunnen verkleind worden door de beenspreiding te vergroten waardoor het zwaartepunt richting craniaal zal verschuiven. Het doel van dit onderzoek is inzicht te geven in de relatie tussen de actieve beenspreiding in de beweging en de effecten die dit heeft op het gevraagde heup- en schoudermoment in het sagittale aanzicht met het idee de benodigde kracht te verminderen zodat jonge sporters de beweging eerder zullen aanleren. Hierbij wordt de vraag gesteld: "Welke relatie bestaat er tussen de actieve beenspreiding en de benodigde heup- en schoudermomenten". Hierbij wordt verwacht dat er een relatie is waarbij een grotere beenspreiding leidt tot een verlaging van de vereiste heup- en schoudermomenten. Er zal een kinematische analyse gemaakt worden van de beweging inclusief een model van de beweging met instelbare beenspreiding die inzicht geeft in de gevraagde gewrichtsmomenten tijdens deze beweging. Tijdens het onderzoek zal alleen gekeken worden naar het deel van de beweging tussen het moment dat de voeten de vloer verlaten en het moment dat de handstand bereikt wordt.

Methode

Er zal een model gemaakt worden van de hefbeweging op basis van een literatuuronderzoek naar de afmetingen en gewichten van het menselijk lichaam en de positie van het LZP. Het model zal bestaan uit drie segmenten. Dit betreft de bovenste extremiteiten, de onderste extremiteiten en de romp, nek en het hoofd samengenomen. Er wordt uitgegaan van een gemeenschappelijk zwaartepunt dat binnen het steunvlak van de handen valt. De benen zullen tijdens het heffen van de romp de maximale heupflexie houden. Nadat de romp geheven is, zullen de benen pas boven horizontaal geheven worden. Dit zorgt ervoor dat de maximale gewrichtsmomenten op verschillende tijdstippen zullen plaats vinden, waarbij de hoek van het andere gewricht bekend is. De polshoek zal bepaald worden door het feit dat het gemeenschappelijke zwaartepunt van het lichaam tussen de handen moet vallen. Het model zal uitgaan van gestrekte benen en armen waarbij de beenspreiding gesimuleerd zal worden door een verkorting van de beenlengte in het sagittale aanzicht. Uit de zwaartepunten van de lichaamssegmenten kunnen de theoretisch maximaal gevraagde gewrichtsmomenten ten gevolge van de zwaartekracht bepaald worden.

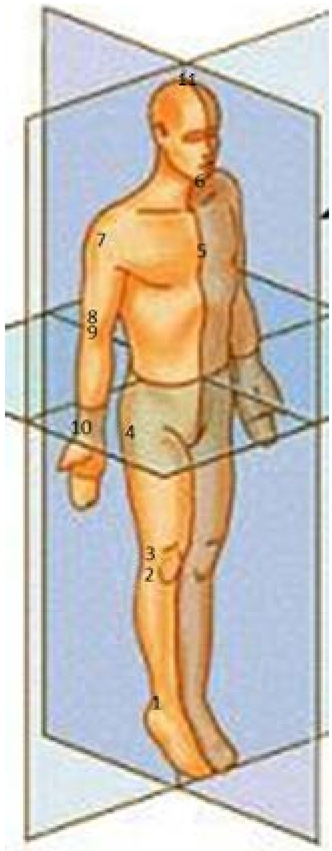
Dataverzameling

Het validatieonderzoek zal metingen beslaan van minimaal vijf turn(st)ers. Allereest zal bij de proefpersonen de grootte van het EMG signaal bij een maximaal vrijwillige contractie (MVC) bepaald worden. Voor het bepalen van het maximale spiermoment van de retroflexoren en bijbehorend MVC van de m. gluteus maximus zal de proefpersoon op de zij liggen en een maximale isometrische contractie uitvoeren tegen een dynamometer geplaatst tegen de ventrale zijde van het bovenbeen op een afstand van 30 cm van de trochanter major. De beweging zal met gestrekt been worden uitgevoerd. Het bepalen van het maximale spiermoment van de schoudergordel rotatoren en het bijbehorende moment van de m. trapezius betreft wederom een maximale isometrische contractie. De proefpersoon dient rechtop te staan met een voorwaarts horizontaal gestrekte arm. De contractie zal uitgevoerd worden tegen een dynamometer geplaatst op de pols. De afstand tussen de tuberculum majus humerus en processus styloides ulnae zal gemeten worden. Verder zal van de proefpersonen het gewicht en de lichaamslengte bepaald worden. Evenals de lengtes van de volgende lichaamssegmenten: het onderbeen, bovenbeen, de romp, het hoofd, de bovenarm en de onderarm.

Hierna zullen per proefpersoon vijf 3D registraties middels een Optitrack systeem gemaakt worden van de proefpersoon die heft tot handstand. Waarbij gelijktijdig een EMG opname gemaakt wordt van de m. gluteus maximus en m. trapezius activiteit. De beweging wordt geregistreerd met markers op de locaties weergegeven in tabel 1 en figuur 2.

Tabel 1: Markerlocaties tijdens de registratie.

Markernummer	Segment	Anatomische positie
1	onderbeen	Maleolus lateralis
2	onderbeen	Condylus lateralis tibialis
3	bovenbeen	Epicondylus lateralis femoris
4	bovenbeen - romp	Trochantor major femoris
5	romp	Manubrium
6	hoofd	Protuberantia mentalis
7	bovenarm	Tuberculum majus humerus
8a	bovenarm	Epicondylus lateralis humerus
8b	bovenarm	Epicondylus medialis humerus
9	onderarm	Circumferentia articularis radii
10a	onderarm	Processus styloides radii
10b	onderarm	Processus styloides ulnae
11	hoofd	Craniale uiteinde cranium



Figuur 3: Globale posities van de markers op het lichaam tijdens de meting.

Deze data zal gebruikt worden om op basis van het onderzoek van Clauser[2] de gemiddelde gewichten van de lichaamsdelen te bepalen. Verder zal tijdens de beweging die geregistreerd wordt ook een EMG meting gedaan worden op de m. gluteus maximus en m. trapezius.

Dataverwerking

De verwerking van de data zal geheel in het sagittale vlak gebeuren, de geregistreerde data zal op dit vlak geprojecteerd worden. De verklaring voor het meten met een 3D-systeem is het feit dat markers met een 2D-systeem uit beeld kunnen raken.

Uit de geregistreerde data is het mogelijk de gewichten[2] en posities van het LZP[2] van de afzonderlijke lichaamsdelen te bepalen. De orientatie van de lichaamsdelen kan worden afgeleid uit het feit dat er per segment twee markers geplaatst zijn, hiermee kan de hoek bepaald worden tussen de richtingscoëfficiënten, dit gebeurt voor de heup, schouder en pols. Uit de positiedata van de lichaamsdelen kan de positie van het samengestelde LZP worden bepaald. Op basis van de zwaartepunten van de lichaamsdelen kunnen de gewrichtsmomenten in de tijd bepaald worden van de schouder en heup. De mate van beenspreiding is middels goniometrie te berekenen uit de verkorting van het been dat in het saggitale aanzicht gemeten wordt. Verder kan op basis van de referentie MVC meting en de gemeten EMG van de beweging het genormaliseerde geleverde moment/kgBW in de tijd bepaald worden. Welke vergeleken kan worden met de voorspelde waarden uit het model.

Statistiek

Uit het model volgt een vergelijking waarin de beenspreiding een voorspellende waarde geeft voor het maximale moment/kgBW nodig voor de beweging. De gemeten waarden worden hiermee gecorreleerd waarna te stellen is of het model de gemeten waarden accuraat representeert.

Bronnen

Artikelen

1) Paulsen, F., & Waschke, J. (2011). *Sobotta: Algemene anatomie en bewegingsapparaat* (4e druk). Houten, Bohn Stafleu Van Loghum.

2) C. E. Clauser, et al. (1969). *Weight, Volume and Center of Mass of Segments of the Human Body*. AMRL-TR-69-70. Ohio: Aerospace medical research laboratory.

Figuren

Figuur 1: FIG. (2015, juli). Men's Artistic Gymnastics Code of Points 2013-2016. Gedownload op 13 januari 2016, van http://www.fig-gymnastics.com/publicdir/rules/files/mag/MAG%20CoP%202013-2016%20(FRA%20ENG%20ESP)%20July%202015.pdf

Figuur 2: R. Schulte. Anatomische vlakken [gemodificeerd voor gebruik in bovenstaande context]. Gedownload op 13 januari 2016, van http://www.ronaldschulte.nl/images/Prep-Anat-begr-fig1.jpg

Planning

werkzaamheden		Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Analyse	■	■	■	■ !												
	Literatuuronderzoek	■	■	■	■												
	Model			■	■												
	Meetapparatuur verkrijgen	■	■														
	Meten	■	■	■	■	■	■	■	■	■	■ !						
	Proefpersonen werven	■	■	■	■	■	■	■									
	Meetprotocol opstellen				■	■											
	Controlemeting					■	■										
	Meten							■	■	■							
	Data controleren									■	■						
	Resultaten		■	■	■	■				■	■	■	■	■ !			
	Software schrijven voor dataverwerking		■	■	■	■											
	Data normaliseren en verwerken											■	■				
	Statistische testen													■			
	Rapportage																
	Artikel	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■ !	
	Inleiding	■	■	■													
	Methoden & Materialen				■	■											
	Resultaten													■			
	Discussie									■	■	■	■	■			
	Conclusie														■	■	
	Samenvatting															■	
	Presentatie			■				■								■ !	
	voorbereiden beeldmateriaal			■				■								■	
	ontwerpen presentatie															■	
	script															■	

(■ = green cell)

	legenda
!	Milestone
■	aan werkend
	niet aan werkend

	Speciale Data
1-mrt	Start Afstuderen
25-mrt	Goede vrijdag
28-mrt	2e paasdag
27-apr	Koningsdag
5-mei	Bevrijdingsdag+Hemelvaartsdag
16-mei	2e pinksterdag
week 12	inleveren 0-scriptie
15-jun	Inleveren eindscriptie
week 16	Verdediging

Appendix 7: Matlab code

```
clear all; close all; clc
plots = true; %boolean, set to false to increase runspeed
%% Anthropometric data
% Initializing array
anthropometry = cell(8,4);
anthropometry(1,2:4)    = {'%BodyWeight' 'Distance to nearest fixed joint'
'Length [m]'};
anthropometry(2:8,1)    = {'Upper Arm' 'Lower Arm' 'Torso' 'Neck and Head'
'Upper Leg' 'Lower Leg' 'Foot'};

% Values from literature
anthropometry(2:8,2:4)  = {...
    6.3  0.56 0.267;...
    3.4  0.57 0.234;...
    45.8 0.50 0.427;...
    8.7  0.50 0.345;...
    22   0.43 0.391;...
    9.8  0.43 0.381;...
    2.6  0.45 0.228};

AnglesClosed =
struct('Shoulder',[98,112,128,137,140,132,139,159,180],'Hip',[105,83,52,52,
67,125,149,172,177]);
AnglesSpread57 =
struct('Shoulder',[140,151,151,147,179,178,178,166],'Hip',[45,43,47,64,89,1
10,140,190]);

InitialHipAngle = linspace(52,36,91);

% Shoulder angle characteristics
shoulderAnglePolynominalLZPMove =
polyfit(AnglesClosed.Hip(1:3),AnglesClosed.Shoulder(1:3),1);
shoulderAnglePolynominalLiftClosed =
polyfit(AnglesClosed.Hip(3:end),AnglesClosed.Shoulder(3:end),2);
shoulderAnglePolynominalLiftSpread57 =
polyfit(AnglesSpread57.Hip,AnglesSpread57.Shoulder,2);

if false
    figure(1)
    hold on
    x = 20:180;
    a = polyval(shoulderAnglePolynominalLiftClosed,x);
    b = polyval(shoulderAnglePolynominalLiftSpread45,x);
    c = polyval(shoulderAnglePolynominalLiftSpread57,x);

    plot(x,a)
    plot(x,b)
    plot(x,c)

    legend('a','b','c')
end

legAbduction = 0:90; % range 0-90 deg
for k = 1:length(legAbduction)
    %% Derived segment data
    % Initializing array
    segmentInfo = cell(4);
    segmentInfo(2:4,1)      = {'Arms' 'Body' 'Legs'};
```

```
    segmentInfo(1,2:4)      = {'%BodyWeight' '%Distance to nearest fixed
joint' 'Length [m]'};

    % Arm
    rArm = (anthropometry{3,2}*(anthropometry{3,3}*anthropometry{3,4}) +
anthropometry{2,2}*(anthropometry{3,4}+(anthropometry{2,3}*anthropometry{2,
4})))/...

(sum(cell2mat(anthropometry(2:3,2)))*sum(cell2mat(anthropometry(2:3,4))));

    segmentInfo(2,2:4)      = {sum(cell2mat(anthropometry(2:3,2))) rArm
sum(cell2mat(anthropometry(2:3,4)))};
    clear rArm

    % Body
    rBody = (anthropometry{4,2}*(anthropometry{4,3}*anthropometry{4,4}) -
anthropometry{5,2}*(anthropometry{5,3}*anthropometry{5,4}))/...

(sum(cell2mat(anthropometry(4:5,2)))*sum(cell2mat(anthropometry(4:5,4))));

    segmentInfo(3,2:4)      = {sum(cell2mat(anthropometry(4:5,2))) rBody
sum(cell2mat(anthropometry(4:5,4)))};
    clear rBody

    % Leg
    rLeg = (anthropometry{6,2}*(anthropometry{6,3}*anthropometry{6,4}) +
anthropometry{7,2}*(anthropometry{6,4}+(anthropometry{7,3}*anthropometry{7,
4})) +
anthropometry{8,2}*(anthropometry{6,4}+anthropometry{7,4}+(anthropometry{8,
3}*anthropometry{8,4})))/...

(sum(cell2mat(anthropometry(6:8,2)))*sum(cell2mat(anthropometry(6:8,4))));

    segmentInfo(4,2:4)      = {sum(cell2mat(anthropometry(6:8,2))) rLeg
(cos(deg2rad(legAbduction(k)))*sum(cell2mat(anthropometry(6:8,4))))};
    clear rLeg


    %% Modelling
    arm = eye(2);% [x1,x2;y1,y2]
    body = eye(2).*2;
    leg = eye(2).*3;

    if plots
        figure(2)
        axis equal
        axis([-0.5 1.500 0 2.000])
        axis off
    end

    %% Phase 1: Move Bodyweight to hands
    if plots
        hipRange = (180:-1:0); % bron sobotta, max anteflexie is 50
        i = 1;
        xLZP = 100;
        while xLZP > 0
            cla

            hipAngle = deg2rad(180-hipRange(i));
```

```
            shoulderAngle = deg2rad(180-
polyval(shoulderAnglePolynominalLZPMove,hipRange(i)));
            wristAngle = 0;

            for n = 1:2
                arm(:,1)  = [0;0];
                arm(:,2)  =
segmentInfo{2,4}*[cos(wristAngle);sin(wristAngle)];
                body(:,1) = arm(:,2) - anthropometry{5,4}*[cos(wristAngle-
shoulderAngle);sin(wristAngle-shoulderAngle)];
                body(:,2) = body(:,1) + segmentInfo{3,4}*[cos(wristAngle-
shoulderAngle);sin(wristAngle-shoulderAngle)];
                leg(:,1) = body(:,2);
                leg(:,2) = leg(:,1) + segmentInfo{4,4}*[cos(wristAngle-
shoulderAngle-hipAngle);sin(wristAngle-shoulderAngle-hipAngle)];
                wristAngle = pi-atan(leg(2,2)/leg(1,2));
            end

            lzpArm  =
segmentInfo{2,4}*[cos(wristAngle);sin(wristAngle)]*segmentInfo{2,3};
            lzpBody = arm(:,2) - segmentInfo{3,4}*[cos(wristAngle-
shoulderAngle);sin(wristAngle-shoulderAngle)]*segmentInfo{3,3};
            lzpLeg = body(:,2) + segmentInfo{4,4}*[cos(wristAngle-
shoulderAngle-hipAngle);sin(wristAngle-shoulderAngle-
hipAngle)]*segmentInfo{4,3};
            combined_lzp = (segmentInfo{2,2}*lzpArm +
segmentInfo{3,2}*lzpBody +
segmentInfo{4,2}*lzpLeg)./sum(cell2mat(segmentInfo(2:4,2)));
            xLZP = combined_lzp(1);

            if plots
                hold on
                plot(arm(1,:),arm(2,:))
                plot(body(1,:),body(2,:))
                plot(leg(1,:),leg(2,:))
                plot(combined_lzp(1),combined_lzp(2),'*k')
                pause(0.01)
                i = i+1;
            end
        end

        hipAngle = round(rad2deg(hipAngle));
    end
    %% Phase 2: raise body to handstand
    hipAngle = round(InitialHipAngle(k));

    for i = hipAngle:180
        if plots; cla;  end
        wristAngle = 0;
        hipAngle = deg2rad(i);

        a = (90-
legAbduction(k))*polyval(shoulderAnglePolynominalLiftClosed,i);
        b =
legAbduction(k)*polyval(shoulderAnglePolynominalLiftSpread57,i);

        shoulderAngle = deg2rad(180-((a+b)/90));
        for n = 1:2
            arm(:,1)  = [0;0];
            arm(:,2)  = segmentInfo{2,4}*[cos(wristAngle);sin(wristAngle)];
```

```
            body(:,1) = arm(:,2) - anthropometry{5,4}*[cos(wristAngle-
shoulderAngle);sin(wristAngle-shoulderAngle)];
            body(:,2) = body(:,1) + segmentInfo{3,4}*[cos(wristAngle-
shoulderAngle);sin(wristAngle-shoulderAngle)];
            leg(:,1) = body(:,2);
            leg(:,2) = leg(:,1) + segmentInfo{4,4}*[cos(wristAngle-
shoulderAngle-(pi-hipAngle));sin(wristAngle-shoulderAngle-(pi-hipAngle))];

            lzpArm  =
segmentInfo{2,4}*[cos(wristAngle);sin(wristAngle)]*segmentInfo{2,3};
            lzpBody = arm(:,2) - segmentInfo{3,4}*[cos(wristAngle-
shoulderAngle);sin(wristAngle-shoulderAngle)]*segmentInfo{3,3};
            lzpLeg = leg(:,1) + segmentInfo{4,4}*[cos(wristAngle-
shoulderAngle-(pi-hipAngle));sin(wristAngle-shoulderAngle-(pi-
hipAngle))]*segmentInfo{4,3};
            combined_lzp = (segmentInfo{2,2}*lzpArm +
segmentInfo{3,2}*lzpBody +
segmentInfo{4,2}*lzpLeg)./sum(cell2mat(segmentInfo(2:4,2)));
            wristAngle= pi+(atan(combined_lzp(1)/combined_lzp(2)));
        end
        shoulderTorque(i) = (lzpBody(1)-
arm(1,2))*segmentInfo{3,2}+(lzpLeg(1)-arm(1,2))*segmentInfo{4,2}; %BW*m
        hipTorque(i) = (lzpLeg(1)-leg(1,1))*segmentInfo{4,2}; %BW*m

        if plots
            hold on
            plot(arm(1,:),arm(2,:))
            plot(body(1,:),body(2,:))
            plot(leg(1,:),leg(2,:))
            plot(combined_lzp(1),combined_lzp(2),'*k')
            pause(0.01)
        end
    end
    maxShoulderTorque(k) = max(shoulderTorque);
    maxHipTorque(k) = max(hipTorque);
end

shoulderTorqueCurve = polyfit(legAbduction,maxShoulderTorque,2);
hipTorqueCurve= polyfit(legAbduction,maxHipTorque,2);

legAbductionPerc = linspace(legAbduction(1),legAbduction(end),100);
percentages = linspace(0,100,100);

Results.Shoulder = polyval(shoulderTorqueCurve,legAbductionPerc);
Results.Hip = polyval(hipTorqueCurve,legAbductionPerc);

Results.Shoulder(Results.Shoulder<0) = 0;
Results.Hip(Results.Hip<0) = 0;

Percentages.Shoulder = Results.Shoulder*(100/max(Results.Shoulder));
Percentages.Hip = Results.Hip*(100/max(Results.Hip));

figure(3)
hold on
subplot(211)
plot(legAbduction,polyval(shoulderTorqueCurve,legAbduction),'k')
xlabel('Hip-abduction [degrees]')
ylabel('Torque [%BW*m]')
ylim([0 25])
title('Results')
```

```
set(gca,'YTick',0:5:25)

subplot(212)
hold on
plot(percentages,Percentages.Shoulder,'k')
xlabel('Hip-abduction [%]')
ylabel('Torque [%]')
set(gca,'box','on')
set(gca,'YTick',0:20:100)

save('Model_Results.mat','legAbduction' ,'shoulderTorqueCurve')
```